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Radiological impact of oil spilled environment: A case study of the Eriemu well 13 and 19 oil spillage in Ughelli region of delta state, Nigeria

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Abstract

A six years of radiation impact assessment in an oil spillage environment and the host communities in Ughelli region of delta state have been conducted, using a digilert nuclear radiation monitor meter and a geographical positioning system (GPS). Measurements were made in 20 sites, 6 host communities and a control sample spread across the affected area. Measured average location values ranged between 0.010 mRh^{-1} (0.532 mSv y^{-1}) to 0.019 mRh^{-1}(1.010 mSv y^{-1}). The yearly exposure rate ranged between 0.013±0.006 mRh^{-1}(0.692±0.080 mSvy^{-1}) to 0.016±0.005 mRh^{-1} (0.851±0.100 mSv y^{-1}) in the oil spillage area. The host communities' values ranged between 0.011 mRh^{-1}(0.585 mSv y^{-1}) to 0.015 mRh^{-1}(0.798 mSv y^{-1}) with an average value of 0.010 mRh^{-1}(0.532 mSv y^{-1}) recorded at the control sample. The radiation levels within these oil spillage areas and the host communities were of 55% and 33.3% respectively above the normal background level of 0.013 mRh^{-1}. The average equivalent dose rate obtained was higher than the 0.478 ηSv/y normal background level but was within the safe limit of 0.05 Sv y^{-1} recommended by ICRP and NCRP. These values obtained will not pose any immediate radiological health hazard to the host communities and workers within this environment.

Keywords: Radiological impact, oil spillage, well 13 & 19, Ughelli region.

Introduction

The earth is radioactive due to natural sources and activities of man in the environment. There is a continuous bombardment of man and his environment by these (radionuclide) ionizing radiations (John & Zordan, 2001). Hence, the issue of environmental degradation and pollution in the 21st century is of global concern, because of its health impact and implications. The quest for oil field development and exploration in the Niger delta of Nigeria had led to various forms of activities that tend to perturb the fragile ecological, biophysical systems and the socio-economic and political structures of the region. Oil and gas industries in the Niger delta are a multi-faceted industry that includes the construction, exploration, and production, downstream and marketing sectors. In most of these sectors, radioactive materials and radiation generators are used on a large scale. The application of these radioactive materials in both offshore and onshore oil and gas industries includes industrial radiography, automatically ionizing radiation gauge, well logging, use of radiotracers in pipes, mapping and evaluation of geological formation and the extraction of other natural hydrocarbon resources (Arogunjo *et al.,* 2004). The interest of the elemental composition and concentration of crude oil arose from the fact that almost all elements of the periodic table are found in crude petroleum and petroleum related products (Nakaimi, 1991)/ It is therefore imperative that crude oil and gas contain some level of natural radionuclide elements which will emits ionizing radiation when exposed to the environment. Kuroda (1991) reported that this background radiation levels are from a combination of terrestrial (^{40}K, ^{232}Th, ^{226}Ra etc) and cosmic radiation (muons, photons etc.). He also reported that the level of radiation is fairly constant over the world, being 0.008-0.015mRh^{-1}. But China, Brazil and India have higher background ionizing radiation; this is primarily due to the high concentration of radioactive minerals (monazite & limonite) that contains high quantity of thorium, uranium and radium in the soil (Kathren, 1991). Avwiri and Ebeniro (1998) studied the external environmental radiation in an industrial area of Rivers state. They reported an average value of 0.14 mRh^{-1} of background ionizing level. The results indicated a slight elevation from the normal background radiation of 0.013 mRh^{-1}. Akinloye *et al.* (2004) studied the indoor radiation exposure rates in some building in Ogbomoso, Nigeria and reported a value range of 1.57-1.89 μRh^{-1}. They concluded that the values obtained are within the limits of 2.0-3.0 μRh^{-1} for areas of normal background radiation. The environmental radioactive level in Ikot Ekpene area of Akwa Ibom state of Nigeria has also been studied by Louis *et al.* (2005) and revealed an average activity level of 201.0±0.05 mBq and radiation level range of 0.007-0.015 mRh^{-1}.

On the effect of oil and gas activities on the radiation level of the environment, Stanislay and Elena (1998) studied the environmental impact of the offshore oil and gas facilities and revealed that production waters from oil and gas production contain naturally occurring radioactive elements (Uranium & thorium) and their daughter progeny (^{226}Ra & ^{228}Ra). There is also a report on radiation safety study of the use of radioactive sources and radiation producing machine for radiographic purposes in the Nigerian petroleum industry (Abison, 2001).

Arogunjo *et al.* (2004) studied the impact of oil and gas industry to the natural radioactivity distribution in Niger delta region of Nigeria and revealed that the mean activity concentrations for ^{40}K, ^{238}U and ^{234}Th radionuclide are 34.8±2.4, 16.2±3.7 and 24.4±4.7 $Bqkg^{-1}$ respectively, with oil extraction activities areas having activities concentration values greater than areas without any known oil extraction activity in the region. Also, the Rail Road Commission of Texas (2007) (www.rrc.statetx.us) reported that naturally occurring radioactive materials (NORM) associated with oil and gas production originate in sub-surface formations which may contain radioactive materials like Uranium and thorium and their daughter products ^{226}Ra and ^{228}Ra. Avwiri *et al.* (2007) measured the terrestrial radiation levels around oil and gas facilities in Ughelli, Nigeria and revealed that the average radiation levels ranges between 12.00±0.1μRh^{-1} (5.33±0.35 μSv/week) to 22.00±2.1 μRh^{-1} (9.79±0.16 μSv/week) in the oil facility field and 09.00±1.0 to 11.00±0.5 μRh^{-1} in the host communities. They concluded that thought the levels with the host communities are within the normal background level, the levels around these oil facilities are far above the normal background level of 0.013 mRh^{-1}. According to the United State Environmental Protection Agency (2006)(www.epa.gov/radiation) field surveys have shown that petroleum pipe scale originating from oil production may have very high ^{226}Ra concentration and on disposal exposes the environment to associated radioactive contamination.

Ughelli and its environs are major onshore oil producing areas in the Niger delta region of Nigeria with a population of about 0.432 million people (NPC Bulletin, 2006). The area, which is one of the highest in oil and gas production onshore of the Niger delta, has over 160 oil and gas wells and five flare stations. It is criss-cross with network of pipelines carrying either oil or gas to the flow stations from the different oil wells. In February 2001, there was a major oil spillage in well 13 and 19 of one of the fields in the area that lasted for four days. It is adjudged the largest oil spillage in the past 20 years in the onshore fields of Niger delta with partial clean up, no recovering and other migration measures on the affected soil and water body (UNDP, 2006). Since this incident, the awareness of the immediate and potential degradation of the water body and the environment by this spillage is on the increase and there have be various claims and counterclaims of loss of wild life and biodiversity, water pollution, loss of use of land affected by the spillage and increase in ionizing radiation levels of the environment by host communities. This study

Table 1. Data obtained from the oil spilled environment.

Sample Location	Geographical Location	Year of Sampling/B.I.R Levels in mRh^{-1}							Eq.dose rate
		2002	2003	2004	2005	2006	2007	Av.B.I.R mRh^{-1}	$mSvy^{-1}$
01	N05^{0}33.491^1 E006^{0}04.883^1	0.017	0.017	0.020	0.018	0.015	0.015	0.017	0.904
02	N05^{0}33.322^1 E006^{0}04.621^1	0.012	0.015	0.018	0.016	0.013	0.010	0.014	0.745
03	N05^{0}32.495^1 E006^{0}03.268^1	0.020	0.019	0.022	0.016	0.015	0.016	0.018	0.956
04	N05^{0}32.545^1 E006^{0}03.194^1	0.020	0.022	0.022	0.020	0.016	0.016	0.019	1.010
05	N05^{0}32.091^1 E006^{0}02.256^1	0.013	0.021	0.020	0.018	0.015	0.015	0.017	0.904
06	N05^{0}32.122^1 E006^{0}02.155^1	0.012	0.014	0.017	0.017	0.020	0.018	0.016	0.851
07	N05^{0}30.520^1 E006^{0}00.779^1	0.008	0.010	0.015	0.016	0.014	0.014	0.013	0.692
08	N05^{0}30.382^1 E006^{0}00537^1	0.011	0.014	0.015	0.012	0.0 13	0.012	0.013	0.692
09	N05^{0}30.191^1 E006^{0}00090^1	0.010	0.010	0.014	0.011	0.008	0.009	.0.010	0.532
10	N05^{0}29.898^1 E005^{0}59.473^1	0.016	0.018	0.018	0.015	0.013	0.014	0.016	0.851
11	N05029.8241 E005^{0}59.326^1	0.010	0.010	0.013	0.013	0.014	0.015	0.013	0.692
12	N05^{0}29.768^1 E005^{0}59.053^1	0.014	0.010	0.013	0.014	0.010	0.012	0.012	0.638
13	N05^{0}29.566^1 E005^{0}58.574^1	0.009	0.012	0.015	0.010	0.009	0.015	0.012	0.638
14	N05^{0}29.651^1 E005^{0}58.782^1	0.013	0.012	0.014	0.012	0.011	0.012	0.012	0.638
15	N05^{0}28.777^1 E005^{0}56.523^1	0-.013	0.014	0.017	0.015	0.013	0.013	0.014	0.745
16	N05^{0}28.562^1 E005^{0}56.436^1	0.013	0.014	0.018	0.014	0.012	0.014	0.014	0.745
17	N05^{0}28.472^1 E005^{0}56.436^1	0.010	0.011	0.013	0.015	0.014	0 .013	0.013	0.692
18	N05^{0}27.894^1 E005^{0}54.772^1	0.015	0.015	0.015	0.013	0.011	0.016	0.014	0.745
19	N05^{0}27.894^1 E005^{0}54.063^1	0.012	0.013	0.018	0.014	0.015	0.014	0.014	0.745
20	N05^{0}27.687^1 E005^{0}53.833^1	0.014	0.013	0.013	0.011	0.013	0.013	0.013	0.692
Mean Values		0.013± 0.006	0.014± 0.005	0.016± 0.005	0.014± 0.004	0.014± 0.007	0.014± 0.004	0.014± 0.006	0.755± 0.086

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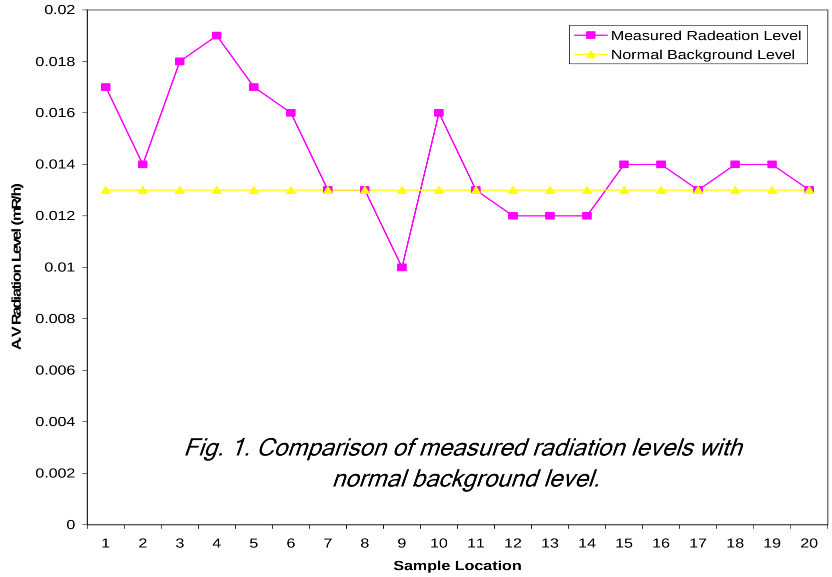

Fig. 1. Comparison of measured radiation levels with normal background level.

therefore is aimed at verifying the later claim. This is done by monitoring the radiation levels of the affected areas and the host communities for six years to ascertain the radiation level and distribution. The radiological health implications of the obtained values were carefully examined and necessary recommendations made.

Materials and methods

This study was conducted between September 2002 and August 2007 in Ughelli region. Ughelli in delta state lies within latitude 05^0, 29N and 05^0, 38N and longitude 005^{0}51E and 006^0, 06E of the Niger delta. The area was divided into twenty measuring sites that were randomly chosen to cover the oil spillage affected environment. Measurements were also taken in the six host communities while one control measurement was taken outside the affected host communities. Measurement were taken twice yearly (winter & summer period) using a digilert nuclear radiation monitor and a geographical positioning system (GPS). An *in-situ* approach was preferred and adopted to enable samples maintain their original environmental characteristics and the same instrument was used for consistency of readings. The tube of the radiation monitoring meter was raised to a standard height of 1 m above the ground (MAFF, 1999) with its window facing first the oil spill environment and then vertically downward while the GPS reading taken at the spot (Avwiri *et al.,* 2007) Reading were obtained between the hours of 1300 and 1600, since the exposure rate meter has a maximum response to environmental radiation within these hours (Louis *et al.,* 2005). Four readings were taken at interval of 5 min. at each of the selected sites and the host communities and average value calculated. Measurements were also taken in a community outside these affected communities as a control experiment.

The count rate per minute was converted to milli-roentengen per hour (mRh^{-1}) using the relation count rate per minute (CPM) = 10^{-3} Roentegen $\times$ Q.F ......(1).

Where QF is the quality factor, which is unity (1) in this case. To estimate the whole body equivalent dose rate, we used the national council of radiation protection and measurements (NCRP, 1993) recommendation, this stipulates that

1mRh^{-1} = (76 $\times$ 0.7) mSvy^{-1}..................(2).

Results and discussion

The results of the measurement obtained are presented in Tables 1 & 2. Table1 shows the exposure rate determined for the twenty sampled locations within the oil spillage area. The average location exposure levels ranges between 0.010 mRh^{-1}(0.532 mSv y^{-1}) in location 10 to 0.019 mRh^{-1}(1.010 mSv y^{-1}) in location 04 with maximum spot exposure rate of 0.022 mRh^{-1} record at locations 03 in 2003 and 04 in 2004 and 2005 respectively. The average yearly exposure rate ranges from 0.13$\pm$0.006 mRh^{-1} (0.692$\pm$0.080 mSv y^{-1}) to 0.016$\pm$0.005 mRh^{-1} (0.851$\pm$0.100 mSv y^{-1}). Year 2002 recorded the least average exposure rate while the highest exposure rate was experienced in 2004.

Table 2 shows the average exposure rate for the 6 years in the host communities and one from another community as control experiment. Omavovwe community which is the main host of the oil well where the spillage occur recorded the mean highest exposure level of 0.015$\pm$0.004 mRh^{-1} (0.798$\pm$0.090 mSv y^{-1}) while the least exposure rate of 0.011$\pm$0.002 mRh^{-1} (0.585$\pm$0.060 mSv y^{-1}) was recorded in Okpare community. The value 0.010$\pm$0.003 mRh^{-1} (0.532$\pm$0.070 mSv y^{-1}) was recorded in the community outside the affected area which shows 33.33% deviation from the value obtained in Omavovwe community. Fig. 1 shows the comparison of the measured values in the sample location with the normal background level while Fig. 2 shows the comparison of the host communities' exposure levels with that of the normal background level. The results of the exposure rate of the oil spillage areas show that eleven (11) locations, which represent 55% of the affected environment, exceeded the normal background level. But these values obtained are within the range of values previous report by Avwiri and Ebeniro (1998), Arogunjo *et al.* (2004) and Avwiri *et al.* (2007) in the Niger delta region. The results obtained in the host communities shows that two out of the six host communities' radiation level exceeded the normal background level but still within the range reported by Akiloye *et al.* (2004), Louis *et al.* (2005) and Agba and Tyovenda (2007) in other communities and town within the country.

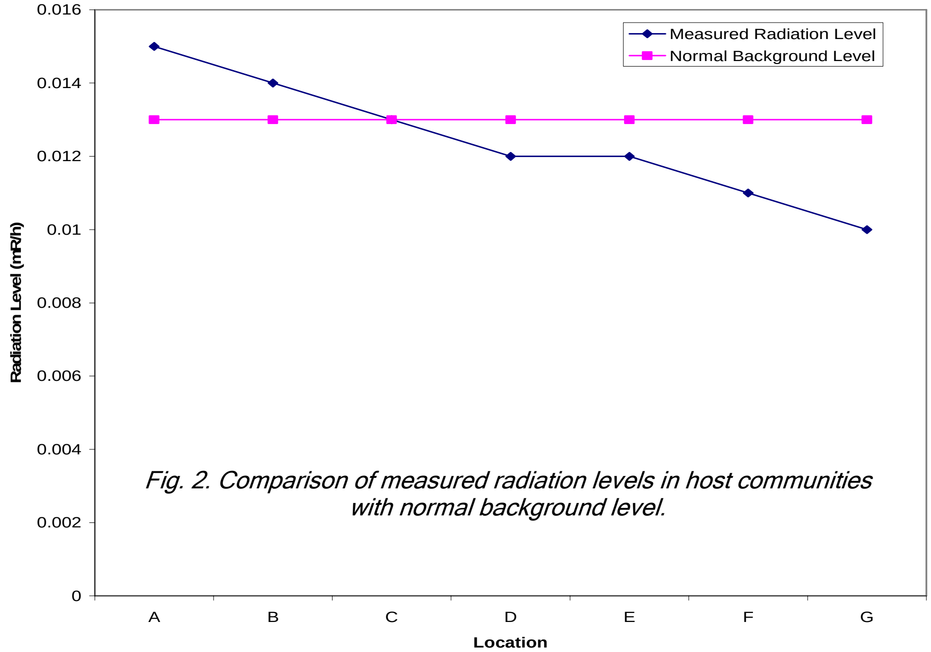

Fig. 2. Comparison of measured radiation levels in host communities with normal background level.

The result of the computed mean effective equivalent dose rate for the host communities and the oil spillage location are 0.624±0.080 mSvy^{-1} and 0.755±0.070 mSv y^{-1} respectively. These values obtained are within the 51±8 μSvy^{-1} value recorded in the eastern zone of Nigeria by Farai and Jibiri (2000) and the 495 mSv y^{-1} recorded by Louis *et al.* (2005) at Ikot Ekpene south-south of Nigeria. The difference in the exposure rate between host communities and the affected environment could be attributed to the heavy metal (unstable radionuclide element) normally associated with crude oil and gas (Nakarmi, 1991; Arogunjo *et al.,* 2004) which impact on this immediate environment. Furthermore, the levels recorded for the host communities are fairly higher than those recorded at Oghara community (control). This could be due to the impact of the oil spillage on the host communities and other oil and gas activities like gas flaring in this environment. These results obtained do not indicate any immediate health side effects on the staff working within these oil installations and pipelines and members of the host communities. The highest effective equivalent dose rate 1.010 mSv y^{-1} recorded at sample location 04 is below the international allowed limits of 0.05 Sv y^{-1} to avoid stochastic effects (ICRP, 1991; NCPR, 1993). Also, since the equivalent dose rate of approximately 0.001 Svy^{-1} is lower than the basic safety standards (BSS) allowed limit. It therefore implies that most of the health side effects traceable to radiation due to the oil spillage by these host communities might be due to other hazardous environmental factor like the use of toxic chemicals and heavy metals by allied companies in the area. However, there is still the likelihood of future health side-effects due to long term accumulation dose at this present level, radionuclide built-up in the atmosphere and the precipitation of produced formation waters (that contain radioactive elements) which on condensation as rain constitute radioactive pollution of rain water. More so, a greater proportion of these formation waters are likely seepage and leached from this oil spillage areas and carried to the sub-surface where they can make contact with underground and sea water. The association radionuclides interact with sulphates in the river and seawater where they partially precipitate and the rest consumed by aquatic animals, hence pose a radiological risk to the aquatic family and beyond (Stanislay *et al.,* 1998). As a result of this indirect ingestion of these radionuclides through the eating of these aquatic animals, the level of exposure and absorption dose rate of radionuclides by the host communities is likely to increase. Thus this trend and degree of exposure and absorption of radionuclide if continued may led to future increase in the incidence of chromosome aberrations, eye cataracts, cause and leukemia in the area (www.macularcentre.com). According to Ballinger (1991), most radiation biology researches describing the quantitative relationship between the radiation dose and biological affect indicates a threshold dose level below which no health side-effects occurs (for short term exposure). Later effects of low-level radiation exposure do not have threshold dose level rather every small exposure exacerbates the health side-effect responsible curve.

Conclusion

The measurement and evaluation of the impact of ionizing radiation in an oil spilled area in Ughelli region of Delta State has been carried out. The study revealed that the terrestrial ionizing radiation level of the area and the host communities have been affected by the oil spillage. Though the equivalent dose rate obtained is still within the permissible radiation limit of 0.05 svyr^{-1} recommended by (ICRP 1991 & NCRP 1993), the radiation levels within the oil spillage areas are fairly above the normal background levels. This shows that crude oil, gas, some of the machines/equipment used and their effluents generate during production processes by these oil companies are radioactive. We draw this conclusion because there has not been any documented or reported evidence of the existence of radioactive materials/ minerals in the sub-soil in the area. Serious health hazard are normally associated with radioactive radiation phenomenon it is therefore necessary to make the following recommendations:

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Table 2. Data obtained from the host communities.

Location code	Host community	Geographical location	Year of sampling/B.I.R levels in mRh^{-1}							Eq. dose rate (mSv/y)
			2002	2003	2004	2005	2006	2007	A.V B.I.R	
A	Omavovwe	N05^{0}32.097^1 E006^{0}02.253^1	0.015	0.016	0.013	0.015	0.015	0.014	0.015	0.798
B	Ekredjebo	N05^{0}30.373^1 E00500.536^1	0.013	0.016	0.014	0.013	0.014	0.013	0.014	0.745
C	Afiesere	N05^{0}27.542^1 E00556.424^1	0.014	0.015	0.012	0.009	0.013	0.012	0.013	0.692
D	Oteri	N05^{0}28.560^1 E005^{0}58.584^1	0.015	0.010	0.011	0.013	0.014	0.010	0.012	0.638
E	Ovwor	N05^{0}27.890^1 E005^{0}54.762^1	0.013	0.015	0.014	0.011	0.012	0.010	0.012	0.638
F	Okpare	N05^{0}27.890^1 E005^{0}53.843^1	0.012	0.011	0.011	0.010	0.012	0.011	0.011	0.585
G	Oghara (Control)	N05^{0}35.016^1 E006^{0}06.812^1	0.010	0.010	0.009	0.009	0.011	0.009	0.010	0.532
Average value			0.013± 0.004	0.013± 0.006	0.012± 0.003	0.011± 0.004	0.013± 0.003	0.011± 0.004	0.013± 0.005	0.624± 0.080

- The oil companies operating in the area should device means of proper clean up and other mitigation measures in the event of oil spillage.
- They should device means of reducing their radionuclide inputs.
- There should be a regular monitoring of ionizing radiation levels in these environment by qualified personnel
- Government agencies responsible for the safety of the environment should enforce all the existing legislations on the environment especially of radioactivity.

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